Olympic National Park
Acoustical Monitoring Snapshot
Summer 2010- Winter 2015

Background Information
In 2015, the Natural Sounds and Night Skies Division received a request to analyze acoustic data that would inform Olympic National Park (OLYM) of potential acoustic impacts caused by the Highway 101 rehabilitation along Lake Crescent. Intermittent acoustical data has been collected from three monitoring sites near the highway corridor from January 2010 to January 2015. These three acoustical monitoring sites provide data describing the current ambient conditions near the 12 miles of road. Analysis of this data along with continued monitoring will determine the impacts from three years of construction activities.

The goal of the technical assistance request was to determine the ambient sound levels as a baseline condition for incorporating impacts of a section of US Highway 101, along Lake Crescent within the park boundary. This is the main artery for travel between the eastern and western portions of the Olympic Peninsula. The project will involve the pulverization of 12.3 miles of two-lane asphaltic concrete, repair of the road base where necessary, and installation of a minimum of six inches of new asphaltic concrete. About 44,269 linear feet of guardrail will also be replaced, along with twenty catch basin grates. One failing gabion wall would be replaced with 120 cubic yards of rip rap. Approximately twenty-five sites along the bank of the lake would also be rip rapped totaling 4000 cubic yards.

This report will provide data on the acoustic environment that will inform the Environmental Assessment (EA). The EA will also include proposals for the use of best available technology and methods to minimize or mitigate anthropogenic noises produced by the equipment and management activities. Baseline data will be and has been gathered using high-quality instrumentation to characterize the acoustic environment of the project area. Acoustic data was collected at three sites within the proposed work area during the summer and winter.

The metrics presented from the recorded data are calculated solely from sound pressure level data, and do not distinguish between intrinsic and extrinsic sound sources. A summary of attended listening sessions provide examples of sound sources heard at the sites.

Study Area

Three sites were monitored adjacent to Highway 101. Table 1 includes the site names and locations. The first site OLYM004 was monitored during the winter of 2010 and summer of 2011 as part of a baseline sound inventory of the entire park. The other two sites OLYM101BP and OLYM101F, as well as OLYM004, were monitored the summer of 2014 and the winter of 2015 and will continue to be monitored during and after construction.

Table 1. Monitoring sites at OLYM

Site	Site Name	Dates	Latitude	Longitude
OLYM004	Pyramid Peak	2010-2015	48.06960	-123.84010
OLYM101BP	Barnes Point	2014-2015	48.05344	-123.79610
OLYM101F	Fairholme	2014-2015	48.06874	-123.92420

Figure 1. The Pyramid Peak site, OLYM004, that was located on the Pyramid Peak Trail. Data was collected here for 6 seasons. Picture was taken the summer of 2014.

Figure 2. The Barnes Point site, OLYM101BP, located south of Highway 101 and west of Barnes Creek Bridge. Two seasons of data have been collected at this site. Picture was taken the summer of 2014.

Figure 3. The Fairhole site, OLYM101F, on the south side of the Highway 101. Two seasons of data have been collected at this site. Picture was taken the summer of 2014.

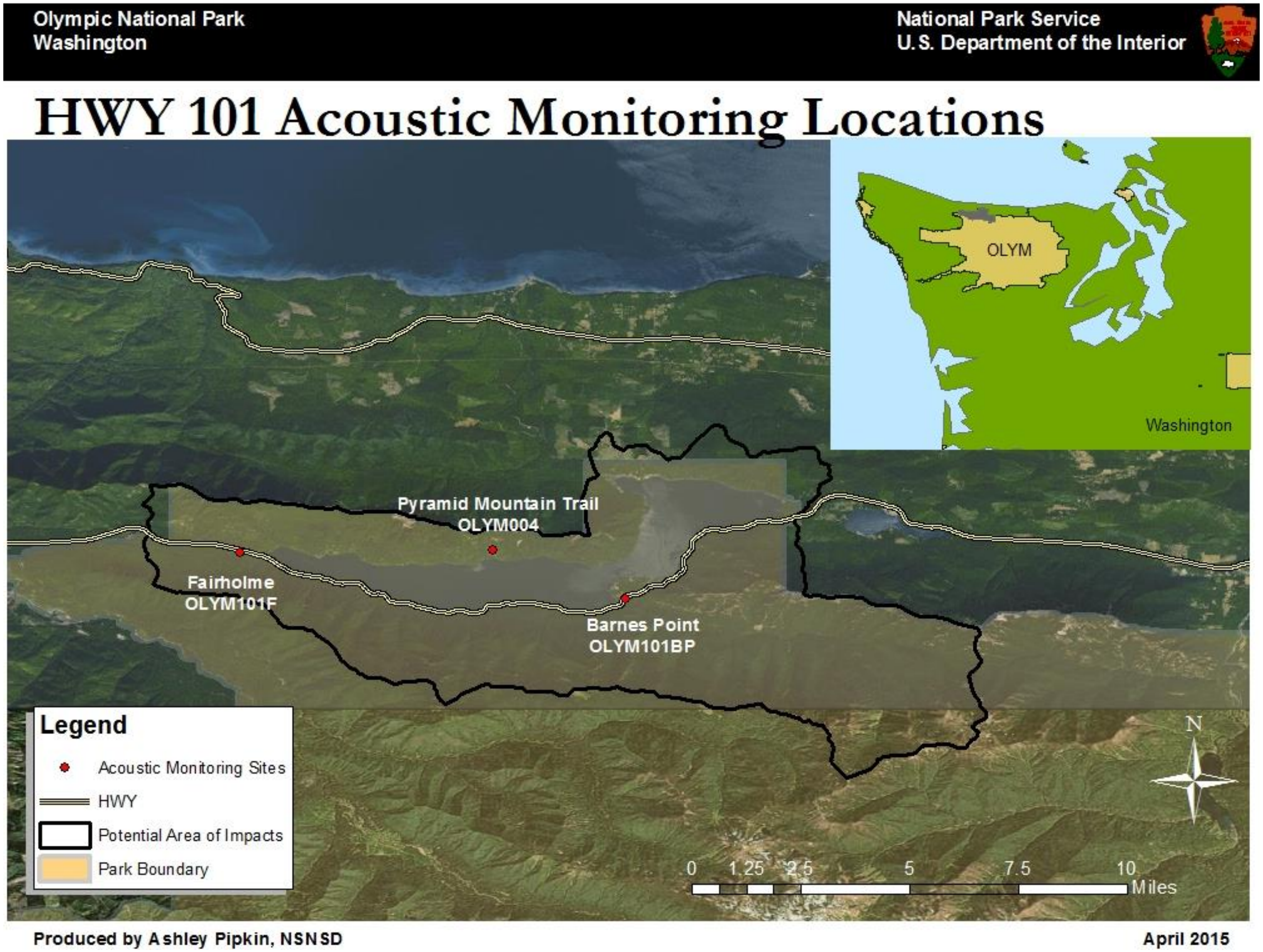


Figure 4. Map of the study area.

Methods & Metrics

At each site, sound pressure level (SPL) measurements were taken, along with digital audio recordings and meteorological data. Larson Davis 831 sound level meters (SLM) were employed over the monitoring periods at each of the OLYM sites. The Larson Davis SLM is a hardware-based, real-time analyzer which constantly records one second sound pressure level (SPL) and 1/3 octave band data. This Larson Davis-based setup met American National Standards Institute (ANSI) Type 1 standards. From these instruments we get 33 SPL measurements each second for a set of frequency bands that span the range of human hearing (12.5 – 20,000 Hz). These 33 measurements approximate the capacity of human listeners to independently sense signals in different parts of the audible spectrum. The SPL is measured in decibels (dB), a logarithmic scale where 0 dB represents the threshold of human hearing at 1 kHz. Microphone measurements can be adjusted according to a weighted scale (A-weighting) such that they resemble the response of the human ear (Harris, 1998).

The logarithmic dB scale can be difficult to interpret, and the functional effect of a seemingly small change in SPL can be greater than anticipated. When noise interferes with hearing natural sounds, the noise is said to *mask* the natural sounds, and this affects the extent of the listening area. For example, if the natural ambient SPL is 30 dB, and transportation noise raises the ambient to 33 dB (a 3 dB increase), the listening area for humans (and many birds and mammals) would be reduced by 50%. Increasing the ambient SPL an additional 3 dB (to 36 dB) would reduce the listening area by half again, to 25% of the initial area. Note, however, that changes in SPL do not proportionately translate to changes in perceived loudness. The rate of change of loudness is complex and dependent on the stimulus itself (SPL, frequency, bandwidth, duration, background, etc.). Table 2 presents park sound sources and other common sound sources with their corresponding A-weighted decibel values (dBA).

Table 2. Sound pressure level examples

Park Sound Sources	Common Sound Sources	dBA
Volcano crater (HALE)	Human breathing at 3m	10
Leaves rustling (CANY)	Whispering	20
Crickets at 5m (ZION)	Residential area at night	40
Conversation at 5m (WHMI)	Busy restaurant	60
Snowcoach at 30m (YELL)	Curbside of busy street	80
Thunder (ARCH)	Jackhammer at 2m	100
Military jet at 100m AGL (YUCH)	Train horn at 1m	120

Table 3 Table 3 summarizes sound pressure levels that relate to human health and speech, as documented in the scientific literature. Human responses can serve as a proxy for potential impacts to other vertebrates because humans have more sensitive hearing at low frequencies than most species (Dooling and Popper, 2007, p. 5). To help interpret the acoustic data collected within the park, and to better understand the implications of the data, it may be helpful to consider sound pressure levels in relation to the functional effects listed in Table 3.

Table 3

Table 3. Effects of sound pressure levels on humans

SPL (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al., 2008)
	Desired background sound level in classrooms (ANSI S12.60-2002)
45	World Health Organization's recommendation for maximum noise levels inside bedrooms (Berglund, Lindvall, and Schwela, 1999)
52	Speech interference for interpretive programs (U.S. Environmental Protection Agency, 1974)
60	Speech interruption for normal conversation (U.S. Environmental Protection Agency, 1974)

Results

For a given frequency range, the *time above* metric indicates the percentage of time that the SPL exceeds a specified decibel value. By comparing the amount of time that sound pressure levels are above certain values, variations in levels can be observed over time (or between sites). Table 4 reports the percent of time that measured levels were above the values in table 3. These values are useful for making comparisons, but should not be construed as thresholds of impact. The top value in each split-cell of Table 4 reports the *percent time above* for the 20 – 1250 Hz range. It is useful to look at this low-frequency range because it includes transportation noise while excluding higher-frequency bird and insect sounds. Transportation is often a major contributor of low frequency sound, but the 20 – 1250 Hz range does not correspond to a specific vehicle or type of transportation. Note that natural sources such as flowing water also produce low frequency sounds. The bottom *percent time above* value in each split-cell is calculated from the full 12.5 – 20,000 Hz range.

Exceedance levels (L_x) represent the sound pressure levels exceeded **x** percent during the given measurement period (e.g. L_{90} is the SPL that has been exceeded 90% of the time). Table 5 reports the L_{90}, L_{50}, and L_{10} values for both sites. For each split-cell in table 5, the top value reports the L_x for the 20 – 1250 Hz subset of the frequency range, and the bottom L_x value is calculated from the 12.5 – 20,000 Hz spectrum. Since the L_{50} represents the sound that is exceeded 50% percent of the time this is the level that represents the existing ambient conditions at the site. We are not reporting the natural ambient (L_{nat}) SPL in this document. The natural ambient would describe the SPL of the area without the presence of human noise. The existing ambient, that we give in this report, includes all noise sources from the area.

Table 4. Percent time above metrics. Winter sampling is highlighted in gray.

Site	Frequency (Hz)	% Time above sound level: 0700 to 1900				% Time above sound level: 1900 to 0700			
		35dBA	45dBA	52dBA	60dBA	35dBA	45dBA	52dBA	60dBA
OLYM004 Winter 2010	20-1250 (T)	34.7	1.4	0.3	0.0	10.8	0.5	0.1	0.0
	12.5-20,000	44.4	2.4	0.6	0.1	18.7	2.5	0.2	0.0
OLYM004 Summer 2010	20-1250 (T)	9.4	0.8	0.3	0.0	2.2	0.1	0.0	0.0
	12.5-20,000	12.1	0.9	0.3	0.0	3.8	0.2	0.0	0.0
OLYM004 Winter 2011	20-1250 (T)	56.5	2.7	1.0	0.2	37.6	0.7	0.2	0.0
	12.5-20,000	87.6	3.7	1.1	0.3	59.0	0.9	0.2	0.0
OLYM004 Summer 2011	20-1250 (T)	28.4	2.1	0.7	0.2	6.9	0.3	0.0	0.0
	12.5-20,000	37.7	3.0	0.8	0.2	15.0	0.4	0.1	0.0
OLYM004 Summer 2014	20-1250 (T)	13.0	1.3	0.4	0.1	3.5	0.2	0.0	0.0
	12.5-20,000	14.6	1.6	0.5	0.1	4.3	0.6	0.1	0.0
OLYM004 Winter 2015	20-1250 (T)	35.4	2.1	0.6	0.1	12.1	0.3	0.0	0.0
	12.5-20,000	67.5	3.0	1.1	0.1	25.9	0.7	0.1	0.0
OLYM101BP Summer 2014	20-1250 (T)	95.6	65.9	32.7	3.5	45.0	19.2	7.0	0.8
	12.5-20,000	96.4	67.3	36.3	4.5	49.0	19.8	7.9	1.0
OLYM101BP Winter 2015	20-1250 (T)	100.0	49.8	22.8	2.9	99.9	14.1	5.6	0.6
	12.5-20,000	100.0	52.6	26.1	3.7	100.0	14.9	6.5	0.8
OLYM101F Summer 2014	20-1250 (T)	79.5	43.8	11.9	1.2	29.3	10.2	2.2	0.2
	12.5-20,000	81.2	47.3	14.6	1.5	31.2	11.3	2.8	0.3
OLYM101F Winter 2015	20-1250 (T)	65.4	30.2	6.8	0.7	19.5	6.7	1.5	0.1
	12.5-20,000	71.4	35.2	10.8	1.1	23.4	8.5	2.2	0.2

Table 5. Exceedance levels for existing conditions. Winter sampling is highlighted in gray

Site	Frequency (Hz)	Exceedance levels (dBA): 0700 to 1900			Exceedance levels (dBA): 1900 to 0700		
		L_{90}	L_{50}	L_{10}	L_{90}	L_{50}	L_{10}
OLYM004 Winter 2010	20-1250 (T)	32.3	37.6	43.6	30.4	33.5	39.0
	12.5-20,000	32.7	38.2	46.7	31.1	34.1	42.4
OLYM004 Summer 2010	20-1250 (T)	28.1	34.7	41.3	23.5	29.8	34.9
	12.5-20,000	28.8	35.3	42.8	24.7	30.8	36.6
OLYM004 Winter 2011	20-1250 (T)	34.2	39.1	47.4	33.3	35.6	40.2
	12.5-20,000	35.6	39.9	48.6	34.9	37.2	41.7
OLYM004 Summer 2011	20-1250 (T)	30.9	37.3	45.4	29.0	32.0	36.5
	12.5-20,000	31.9	38.3	46.7	30.1	33.4	38.6
OLYM004 Summer 2014	20-1250 (T)	26.9	35.1	41.7	19.4	28.5	34.9
	12.5-20,000	27.6	35.5	42.5	22.9	30.2	36.0
OLYM004 Winter 2015	20-1250 (T)	32.5	37.6	44.8	31.3	33.8	37.6
	12.5-20,000	34.3	38.7	47.2	33.6	35.6	39.2
OLYM101BP Summer 2014	20-1250 (T)	38.8	56.8	62.0	31.8	48.2	56.5
	12.5-20,000	39.2	57.4	62.5	32.4	48.8	56.9
OLYM101BP Winter 2015	20-1250 (T)	36.0	45.1	56.2	38.0	55.8	61.7
	12.5-20,000	38.7	56.5	62.5	37.0	46.4	56.9
OLYM101F Summer 2014	20-1250 (T)	32.4	52.5	59.5	21.4	43.1	51.6
	12.5-20,000	33.0	53.2	60.0	22.3	44.3	52.5
OLYM101F Winter 2015	20-1250 (T)	28.4	50.8	58.0	23.6	39.2	50.9
	12.5-20,000	30.1	52.2	59.1	25.6	41.6	52.5

High frequency sounds (e.g. a cricket chirping) and low frequency sounds (e.g. transportation noise) often occur simultaneously, and do not always occur constantly throughout the day. Figures 5-14 illustrate these concepts by dividing the full frequency spectrum into 33 smaller frequency bands (each encompassing a one-third octave range), and by plotting the daytime and nighttime SPL range for each band. The ability of humans to hear a given sound is dependent upon the frequency and the amplitude (in dB) of the sound. The grayed area in the background of the graphs represents sound pressure levels outside of the typical range of human hearing. The typical frequency ranges for transportation, conversation, and songbirds are presented on the figures as examples for interpretation of the data. These ranges are estimates and are not vehicle, species, or habitat specific.

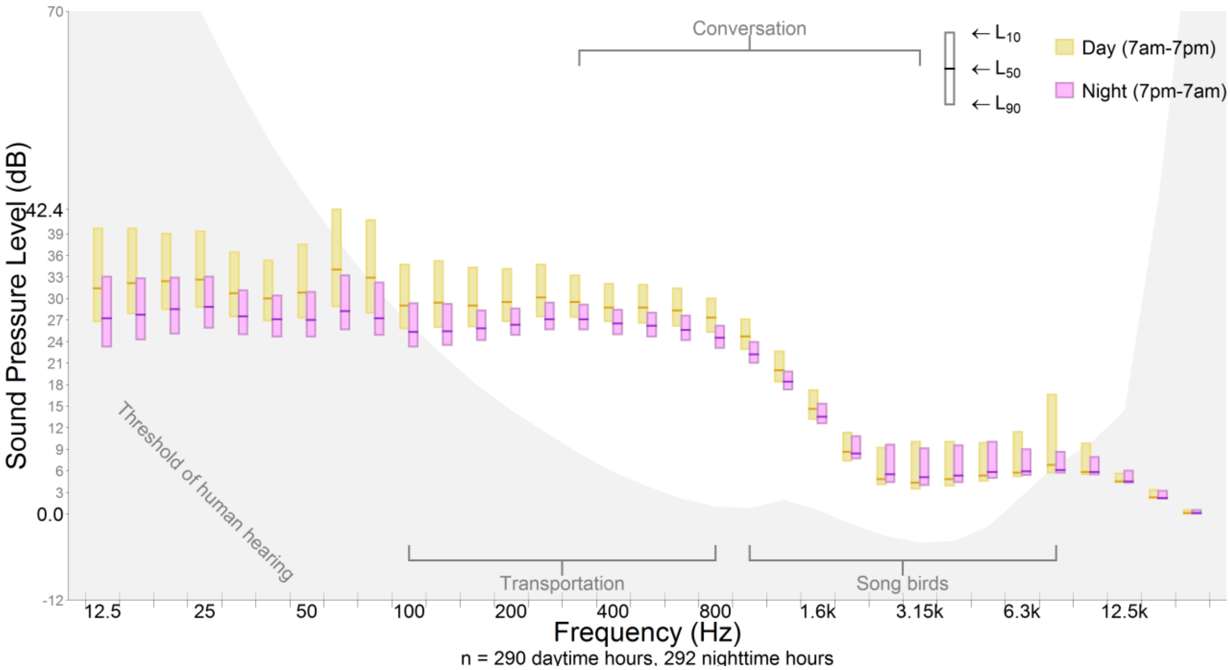


Figure 5. Day and night dB levels for 33 one-third octave bands at OLYM004 for 13 days in winter 2010.

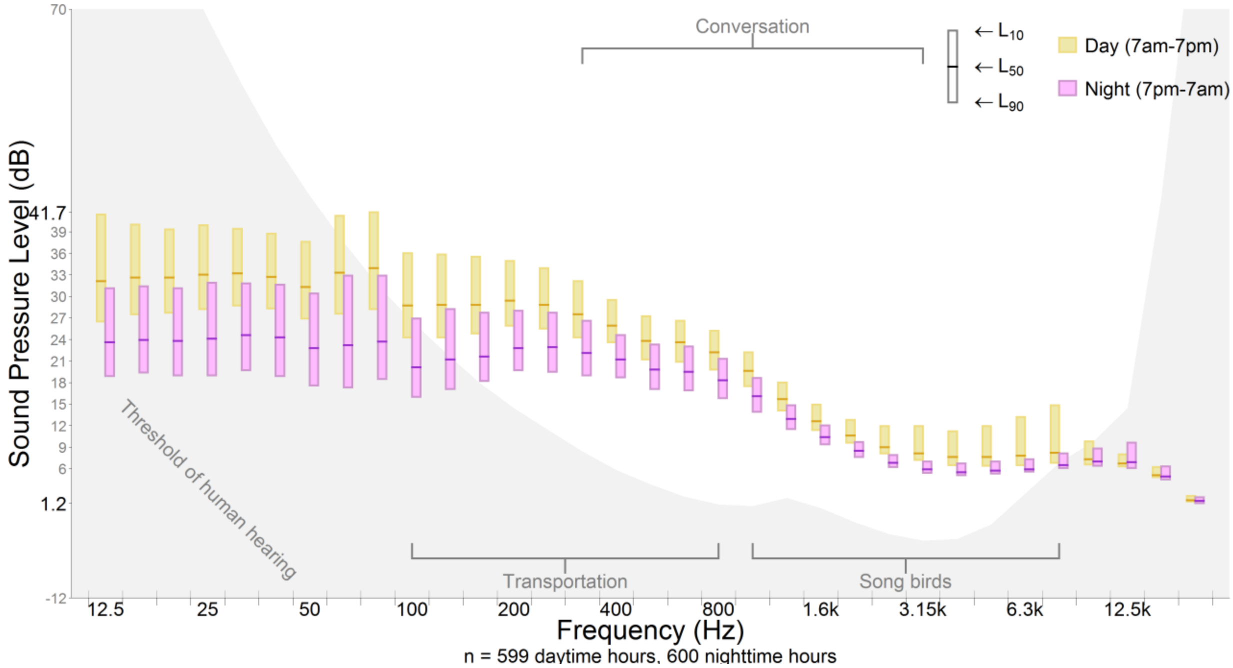


Figure 6. Day and night dB levels for 33 one-third octave bands at OLYM004 for 25 days in summer 2010.

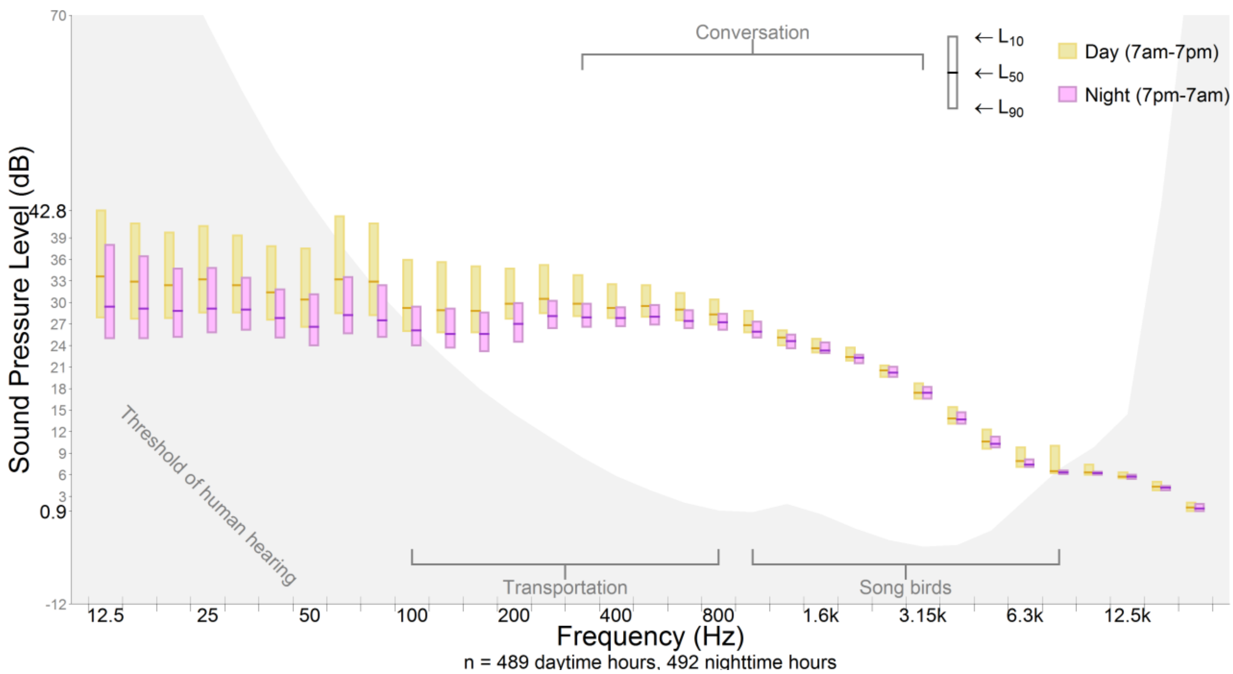


Figure 7. Day and night dB levels for 33 one-third octave bands at OLYM004 for 21 days in winter 2011.

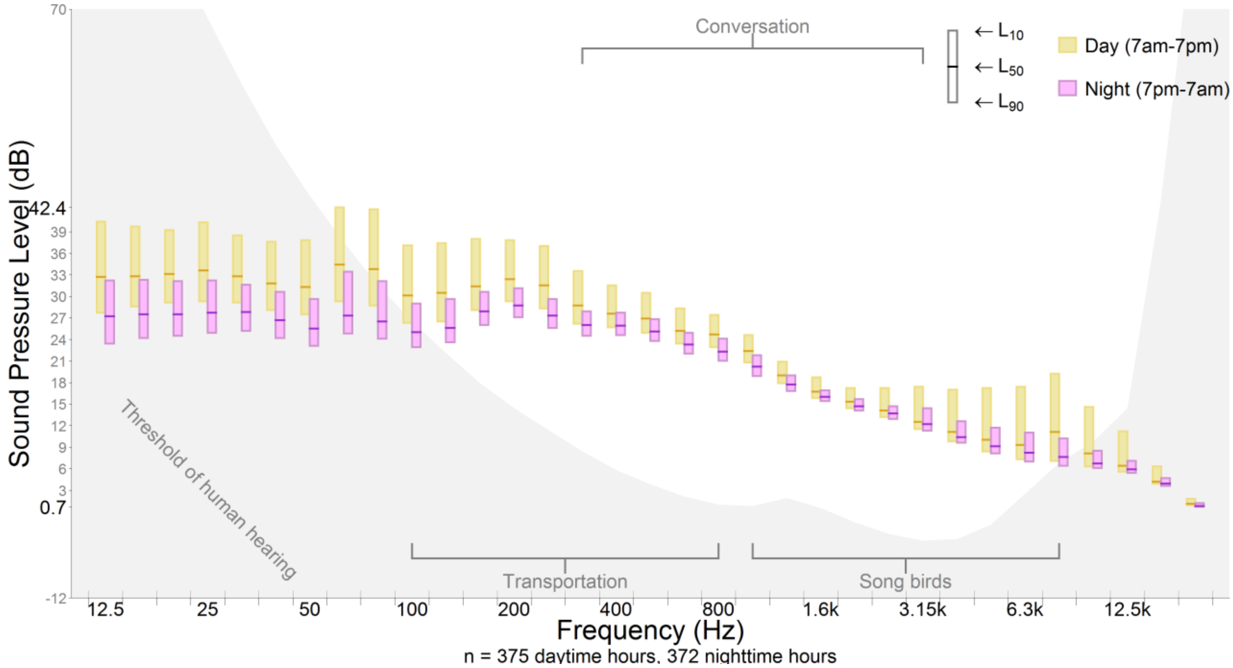


Figure 8. Day and night dB levels for 33 one-third octave bands at OLYM004 for 16 days in summer 2011.

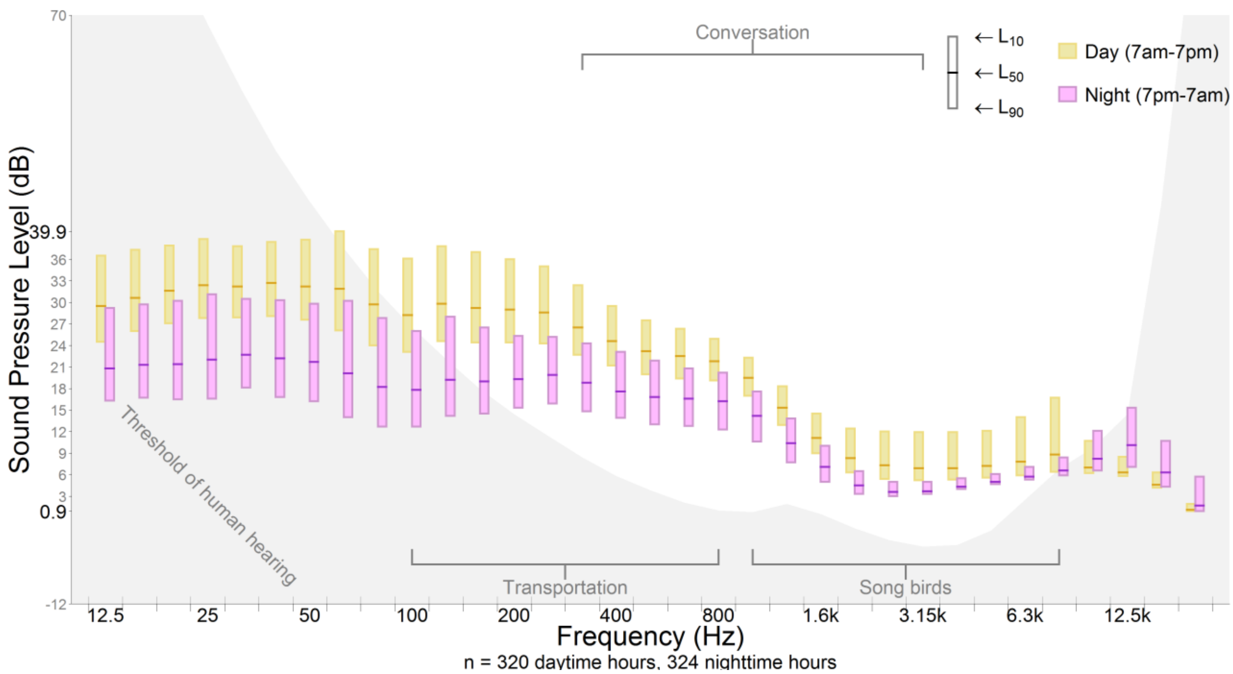


Figure 9. Day and night dB levels for 33 one-third octave bands at OLYM004 for 14 days in summer 2014.

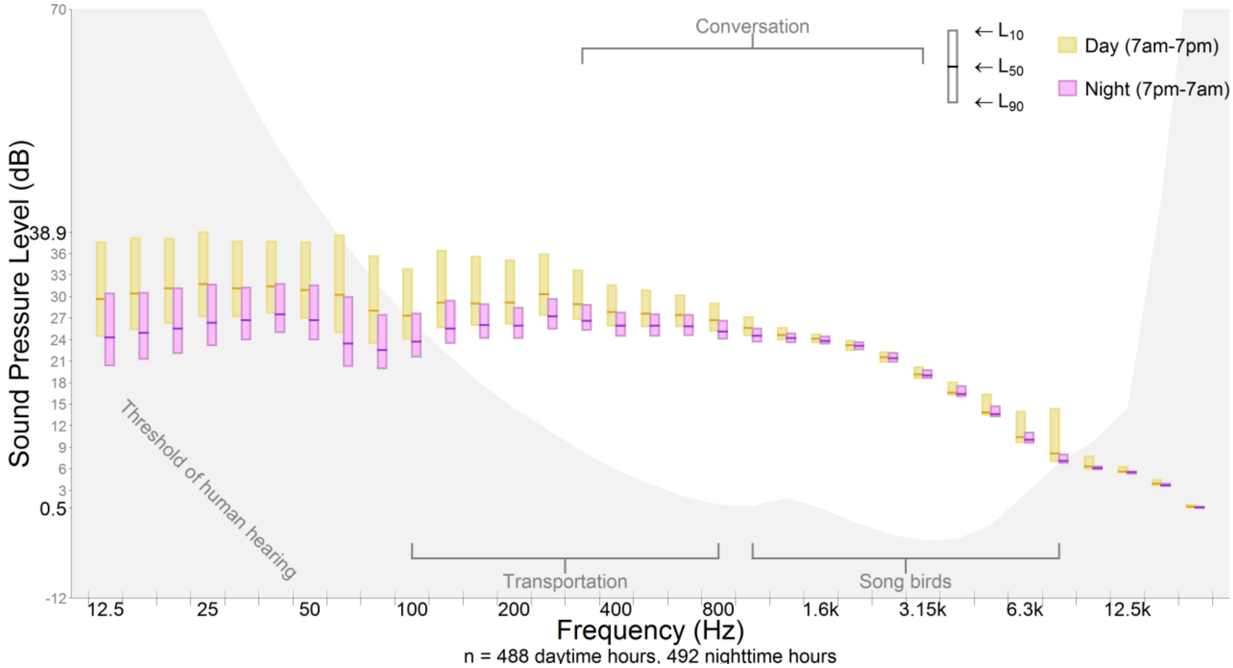


Figure 10. Day and night dB levels for 33 one-third octave bands at OLYM004 for 21 days in winter 2015.

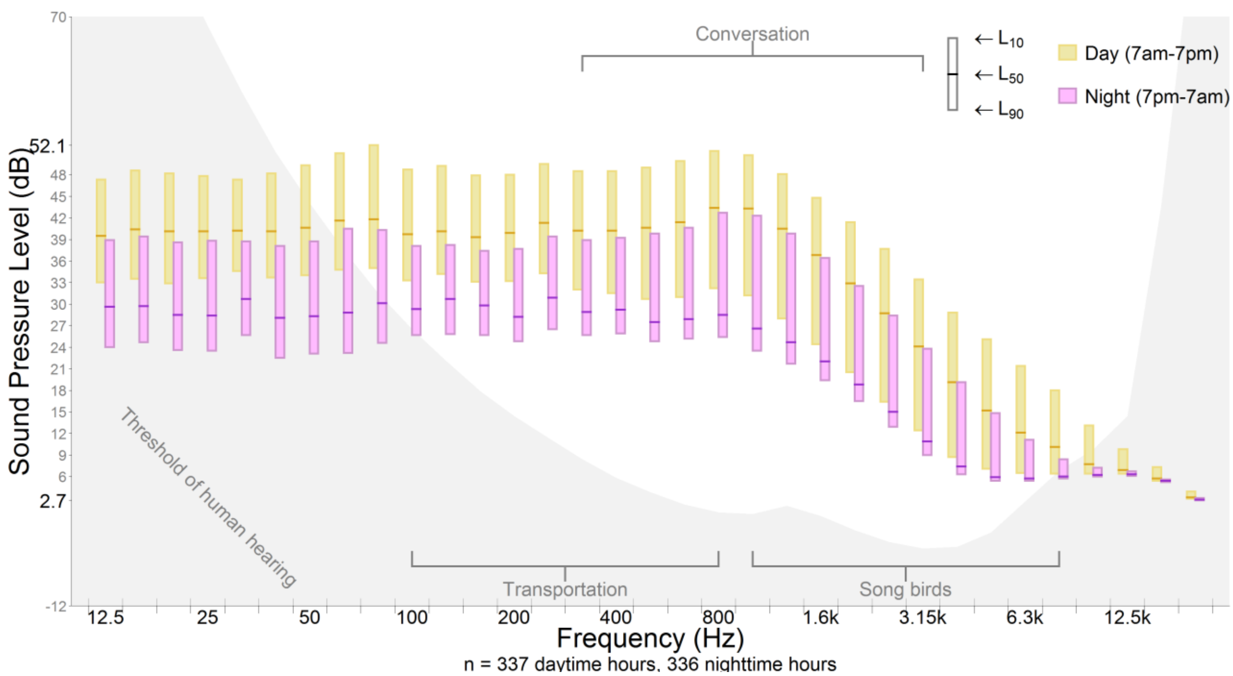


Figure 11. Day and night dB levels for 33 one-third octave bands at OLYM101BP for 15 days in summer 2014.

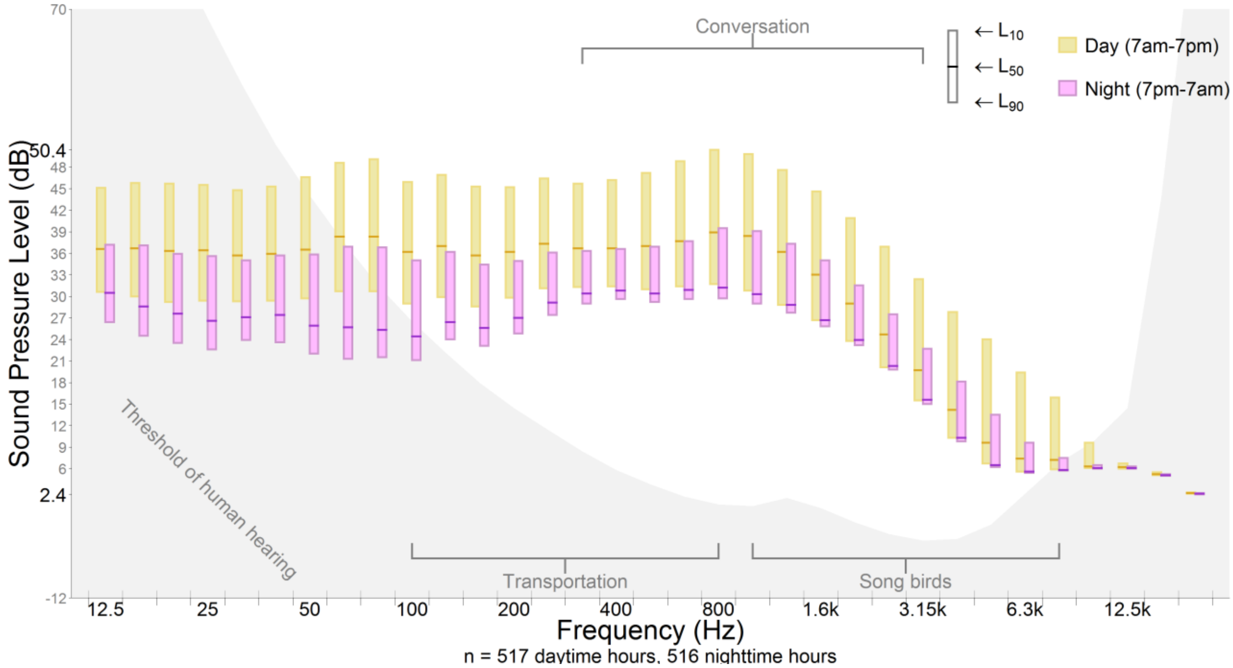


Figure 12. Day and night dB levels for 33 one-third octave bands at OLYM101BP for 22 days in winter 2015.

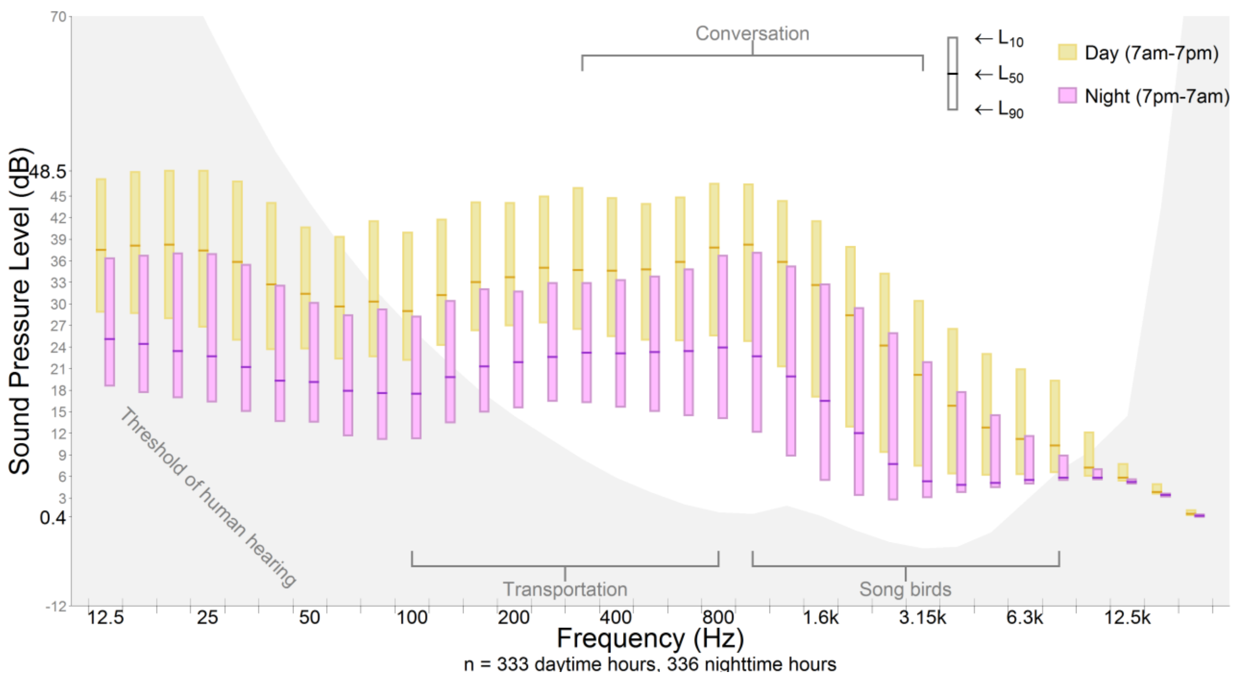


Figure 13. Day and night dB levels for 33 one-third octave bands at OLYM101F for 14 days in summer 2014.

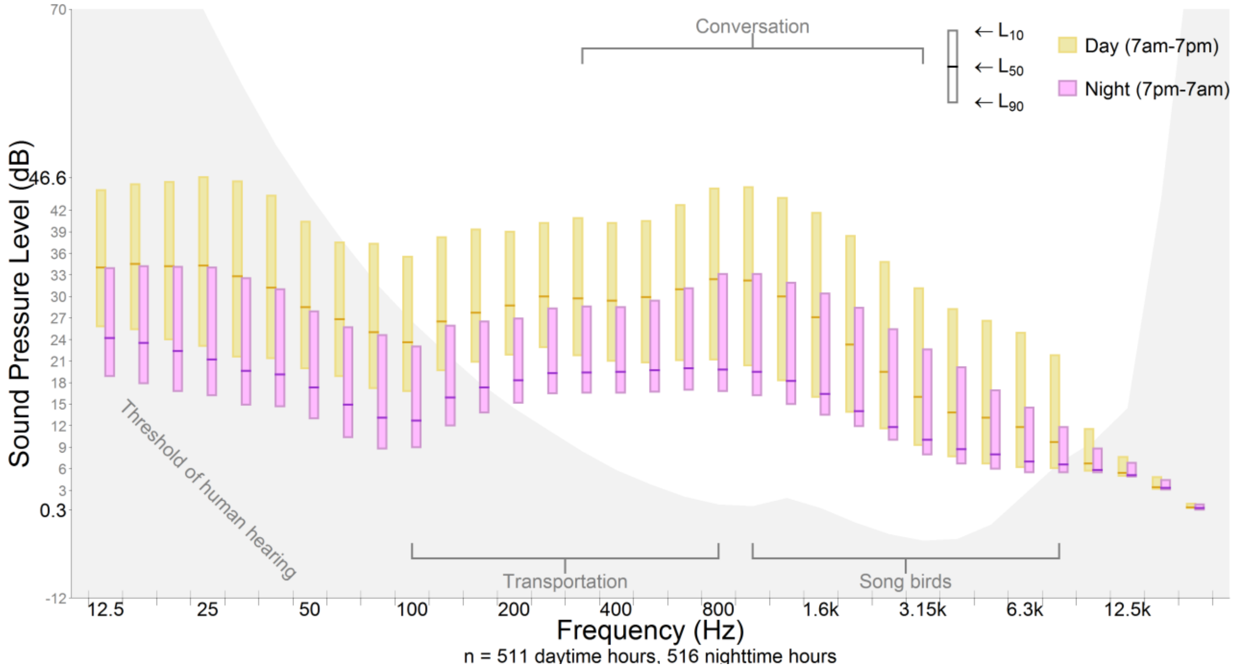


Figure 14. Day and night dB levels for 33 one-third octave bands at OLYM101F for 22 days in winter 2014.

On-site Listening

Tables 6-12 display the results of the on-site listening sessions at OLYM. Each audible sound source is listed in the first column. Percent time audible, or PA, is in the second column. The third column, Max Event, reports the maximum event length among the sessions for each sound source. Likewise, Mean Event and Min Event columns report the mean and minimum length of events, respectively. Std Dev reports the standard deviation among event lengths, and the Events column reports the discrete occurrences of each sound source. The last row in the table, noise free interval (NFI), is a metric which describes the length of time between extrinsic or human-caused events (when only natural sounds were audible). The NFI row and the Max Event, Mean Event, Min Event, and Std Dev columns are reported in minutes:seconds. These on-site listening tables are essentially a sound inventory of each site. These tables represent the sounds one is likely to hear at or near this location. All of these sessions were conducted during the daytime so they may not be representative of diurnal changes at the site. In the following tables anthropogenic noises that are likely related to the presence of highway 101 are highlighted in grey.

Table 6. Summary of on-site audible sound sources for Pyramid Peak (OLY004) n=3 hour-long sessions in the winter of 2010 during the daytime. Events are counted and measured in minutes:seconds.

Sound Source	PA (%)	Max Event	Mean Event	Min Event	SD Event	Events
Jet	14	05:01	01:40	00:06	01:25	15
Vehicle	98	59:53	13:32	00:14	16:44	13
Truck	4	01:14	00:21	00:02	00:19	20
Heavy Truck	15	06:40	00:43	00:00	01:11	37
People, Voices	0	00:33	00:33	00:33		1
People, Walking	0	00:31	00:31	00:31		1
Mammal	0	00:02	00:02	00:02		1
Bird	40	12:51	02:45	00:02	03:26	26
Noise Free Interval	0.2	00:09	00:04	00:01	00:03	6

Table 7. Summary of on-site audible sound sources for Pyramid Peak (OLY004) n=3 hour-long sessions in the summer of 2014 during the daytime. Events are counted measured in minutes:seconds.

Sound Source	PA (%)	Max Event	Mean Event	Min Event	SD Event	Events
Jet	11	06:35	02:31	00:04	02:23	8
Aircraft, Propeller	0	00:51	00:51	00:51	00:01	1
Prop, General Aviation	0	00:21	00:21	00:21	00:01	1
Vehicle	32	31:09	11:25	01:06	12:36	5
Automobile	49	30:39	22:16	00:08	14:46	4
Heavy Truck	26	06:07	00:55	00:00	01:20	52
Heavy Equipment	26	16:15	02:18	00:00	03:36	20
People, Walking	0	00:01	00:01	00:01	00:01	1
Non-natural Unknown	1	01:13	01:13	01:13	00:01	1
Wind	26	03:44	01:11	00:01	00:48	40
Wind, Light	23	04:08	01:02	00:06	01:02	40
Squirrel	0	00:08	00:03	00:00	00:04	4
Chipmunk	2	02:05	00:26	00:00	00:37	10
Bird	26	11:42	00:17	00:00	01:12	167
Insect	0	00:00	00:00	00:00	00:01	1
Natural Other	0	00:06	00:01	00:00	00:01	48
Natural Unknown	0	00:13	00:02	00:00	00:03	15
Noise Free Interval	16.4	29:19	05:54	00:01	13:05	5

Table 8. Summary of on-site audible sound sources for Pyramid Peak (OLY004) n=3 hour-long sessions in the winter of 2015 during the daytime. Events are counted and measured in minutes:seconds.

Sound Source	PA (%)	Max Event	Mean Event	Min Event	SD Event	Events
Jet	16	04:56	02:37	00:15	01:36	11
Prop, General Aviation	2	01:29	01:19	01:09	00:10	3
Vehicle	29	27:06	17:39	00:21	15:00	3
Automobile	67	59:59	59:58	59:57	00:01	2
Heavy Truck	31	09:40	01:21	00:01	02:17	41
Heavy Equipment	6	05:50	01:02	00:05	01:39	11
Non-natural Unknown	0	00:13	00:08	00:02	00:08	2
Wind	1	01:12	00:39	00:20	00:23	4
Wind, Light	0	00:08	00:08	00:08	00:00	2
Flowing Water	99	59:52	59:36	59:17	00:18	3
Bird	18	04:10	00:21	00:00	00:46	90
Noise Free Interval	0.1	00:11	00:04	00:01	00:05	4

Table 9. Summary of on-site audible sound sources for Barnes Point (OLYM101BP) n=4 hour-long sessions in the summer of 2014 during the daytime. Events are counted and measured in minutes:seconds.

Sound Source	PA (%)	Max Event	Mean Event	Min Event	SD Event	Events
Jet	11	03:10	01:13	00:03	00:56	16
Prop, General Aviation	1	02:26	02:26	02:26		1
Automobile	100	59:58	35:58	00:48	25:27	5
Vehicle Door	0	00:01	00:01	00:00	00:01	7
Motorcycle	6	02:17	00:38	00:02	00:37	16
Bus	0	00:32	00:20	00:08	00:17	2
Heavy Traffic	24	04:23	00:45	00:00	00:43	59
People, Voices	1	00:36	00:04	00:00	00:08	29
Dog	0	00:01	00:01	00:01	00:00	2
Non-natural Unknown	4	04:11	00:12	00:00	00:45	36
Wind	22	07:25	01:00	00:01	01:27	40
Light Wind	6	01:34	00:18	00:02	00:24	35
Chipmunk	0	00:27	00:06	00:00	00:09	9
Bird	1	00:47	00:02	00:00	00:06	63
Natural Other	1	00:09	00:01	00:00	00:02	62
Natural Unknown	0	00:01	00:00	00:00	00:01	5
Noise Free Interval	0.1	00:02	00:02	00:02	00:00	4

Table 10. Summary of on-site audible sound sources for Barnes Point (OLYM101BP) n=4 hour-long sessions in the winter of 2015 during the daytime. Events are counted and measured in minutes:seconds.

Sound Source	PA (%)	Max Event	Mean Event	Min Event	SD Event	Count
Jet	17	04:37	02:13	00:07	01:16	18
Vehicle	50	59:38	14:52	00:19	20:42	8
Automobile	25	29:41	11:58	00:20	14:00	5
Motorcycle	0	00:32	00:26	00:20	00:08	2
Bus	1	00:34	00:28	00:24	00:06	3
Heavy Truck	10	01:50	00:42	00:01	00:29	33
Heavy Equipment	32	00:13	02:58	00:01	11:43	26
Wind	5	06:19	01:11	00:00	01:49	11
Light Wind	0	00:09	00:09	00:09		1
Water	6	02:28	00:33	00:02	00:33	24
Flowing Water	48	58:47	57:18	55:50	02:05	2
Squirrel	1	01:56	00:48	00:05	01:00	3
Chipmunk	2	03:20	01:59	00:38	01:55	2
Bird	41	16:49	00:46	00:00	02:17	130
Bachman's Sparrow	0	00:07	00:07	00:07		1
Noise Free Interval	0.1	00:07	00:04	00:01	00:02	5

Table 11. Summary of on-site audible sound sources for Fairholme (OLYM101F) n=4 hour-long sessions in the summer of 2014 during the daytime. Events are counted and measured in minutes:seconds.

Sound Source	PA (%)	Max Event	Mean Event	Min Event	SD Event	Count
Jet	9	02:38	01:25	00:10	00:50	15
Prop, General Aviation	2	02:25	01:22	00:26	01:00	3
Vehicle	25	59:39	29:59	00:19	41:57	2
Automobile	74	59:59	22:20	00:06	24:26	8
Motorcycle	0	00:24	00:16	00:08	00:07	4
Bus	0	00:22	00:22	00:22	00:01	1
Heavy Truck	22	03:00	00:41	00:01	00:33	78
Heavy Equipment	8	01:28	00:35	00:04	00:25	32
Wind	0	00:10	00:05	00:01	00:03	6
Light Wind	5	01:42	00:27	00:03	00:24	25
Chipmunk	4	02:29	00:20	00:00	00:33	32
Bird	52	16:57	00:37	00:00	02:07	205
Natural Other	0	00:02	00:00	00:00	00:01	7
Natural Unknown	0	00:01	00:00	00:00	00:01	4
Noise Free Interval	0.3	00:29	00:07	00:01	00:10	7

Table 12. Summary of on-site audible sound sources for Fairholme (OLYM101F) n=4 hour-long sessions in the winter of 2015 during the daytime. Events are counted and measured in minutes:seconds.

Sound Source	PA (%)	Max Event	Mean Event	Min Event	SD Event	Count
Aircraft	1	01:12	00:45	00:18	00:38	2
Jet	14	07:14	02:52	00:42	01:47	12
Prop, General Aviation	2	02:47	01:56	01:06	01:11	2
Vehicle	23	35:40	07:04	00:38	11:47	8
Automobile	72	54:07	14:32	01:30	16:37	12
Bus	0	00:33	00:30	00:28	00:04	2
Heavy Truck	17	02:59	00:45	00:00	00:35	54
Non-natural Unknown	0	00:09	00:04	00:01	00:04	3
Light Wind	0	00:22	00:22	00:22		1
Rain/Fog Drip	0	00:01	00:01	00:01		1
Squirrel	0	00:10	00:10	00:10		1
Chipmunk	5	06:30	00:40	00:00	01:29	19
Bird	81	59:46	01:12	00:00	04:50	163
Insect	0	00:01	00:01	00:01		1
Noise Free Interval	1.3	01:34	00:24	00:03	00:33	8

Species of Special Concern

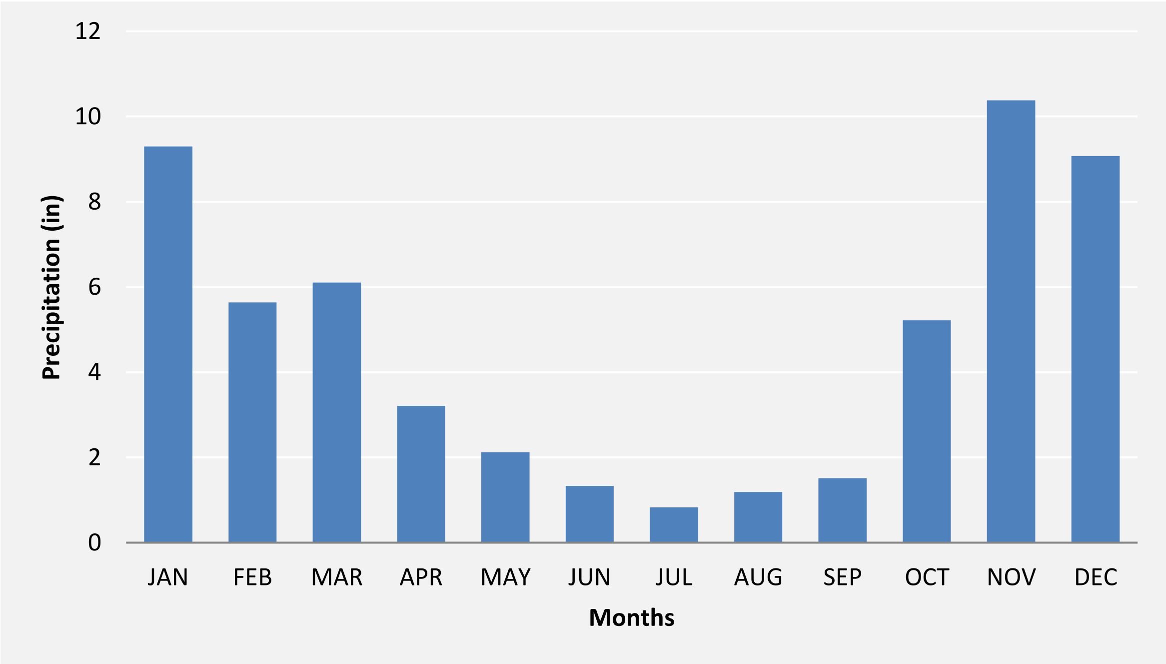
Monitoring sound levels are important for multiple reasons including impacts to wildlife behavior and breeding (Barber et. Al 2009). Construction will be occurring in areas that will require a survey of, two endangered birds, the Marbled Murrelet (*Brachyramphus marmoratus*) and the Spotted Owl (*Strix occidentalis*). These two species are acoustically sensitive (USFWS 2008). Project generated noise in excess of 20-25 decibels above the current L_{50} can be considered harassment and loud noises should be minimized (USFW 2006). Obtrusive noises during nesting (April to Sept) can lead to increases in chick mortality. In the presence of loud disturbances parents will not return to the nest to feed chicks. Nesting is typically from April 1-August 5, while sensitivity is increased during the dawn and dusk feeding times from August 5 to Sept 15 (USFWS 2008). Currently there is a 70 yard buffer adjacent with Highway 101 that includes 189 acres of disturbed habitat for Marbled Murrelets (USFWS 2008). The park may want to consider temporarily increasing this buffer due to the increase in noise disturbance from construction activities. The Spotted Owl populations are restricted to the high elevation zones of the park (pers communication with park staff). The range of these birds has been severely constricted in the region with the increase of Barred Owls (*Strix varia*) in the area (Holmgreen et. Al 2014). The Highway 101 rehabilitation will be done in a low elevation portion of the park that already has a high level of noise disturbance from the highway and would likely not be very suitable habitat for this species. If surveys show that either of these species nest in or near the area of construction temporal noise restrictions will have to be put in place to prevent disturbing these birds. Follow-up information and monitoring interpretation can be provided if these species will be impacted.

Discussion

Park transportation corridors, like the one surveyed in this study, have median ambient sound levels that are typically more than four orders of magnitude higher than the natural condition (Barber et. Al. 2009). Without analysis of the digital audio recordings, it can be hard to attribute noise to any single noise source. However, the geography of a location and what we know about road corridors in other areas can help park managers draw conclusions about common sound sources that also have identifiable characteristics provided by the data. For example, the low frequency noise or truncated frequencies in tables 4 and 5 can most commonly be attributed to transportation, wind and the sounds that emanate from flowing water or rain. Traffic along this corridor also follows a pattern. The traffic is generally heavier on this stretch of highway during the summer months than the winter months and during the daytime than the nighttime.

There are also some climatic conditions that are predictable, in addition to what we know about the traffic. Data provided from National Climatic Data Center shows a large discrepancy in precipitation from summer to winter. The winter is much wetter than summer months and one can expect the natural ambient SPL in these months to be higher due to this pattern. Figure 15 shows thirty year (1981-2010) averages for monthly precipitation at ELWHA RS weather station, located less than five miles from the potential area of impact. High winds can also increase the decibel levels at lower frequencies. While there is no significant seasonal variation in wind speeds there does seem to be typically lower wind speeds in summer and early fall, resulting in a lower contribution to natural ambient sound pressure. The figures in the discussion section make interpretation of the data presented more clear.

Figure 15. Average monthly precipitation averaged over 30 years for Elwha Range Station, located less than 5 miles away from the potential area of impacts.



When looking at the map (Figure 4) we can see that OLYM101BP and OLYM101F are much closer to the highway than OLYM004, these first two sites represent an acoustic environment dominated by the sounds from the road corridor. Overall, measured sound levels at OLYM101BP and OLYM101F were higher than OLYM004, respectively (Figures 16-17). OLYM004 is separated from the road by Crescent Lake. While the lake does not block sound in the same way a forest or mountain could the distance from the road will cause the sounds from the road corridor to attenuate. During this process of attenuation we can expect the low frequencies from traffic to loose less power (dBA) than the high frequency sounds from traffic as they travel to the microphone. The daytime low frequency peaks in figures 5-8 at OLYM004 likely represent traffic noise from this site. It is also worth noting the high frequency peak that is evident in the right portion of the graph that is likely caused by the dawn chorus at OLYM004. The proximity of the 101BP and 101F site to the road makes it more likely that these stations will pick up both the high and low frequency noises from traffic, the broadband energy is greater at these sites as seen in Figures 11-14. This increased broadband energy represents more than just the sound of the motor. In addition to the motor other vehicular noise like the sound of the tire on the road and the air flow over the car is picked up making the site louder in all frequencies.

The differences between these three sites are important when understanding the daily and seasonal differences shown in the data. When comparing all three sites we should expect increased decibel levels in the summer (high traffic season) from the OLYM101F and the OLYM101BP sites. The OLYM004 site should have higher decibel levels in the winter (high water flow season) because the acoustic environment is not dominated by the highway. These are the patterns the data shows. At OLYM004 the sound of flowing water in the winter is likely masking the sounds coming from Highway 101, because the sounds from the road corridor are louder at the OLYM101BP and OLYM 101F site they will likely mask the sounds of flowing water. When a sound source masks another both combine to make a louder acoustic environment.

Figure 16: The exceedance levels from the loudest 10% of sound pressure levels over the course of a typical day at all three sites, during each monitoring season.

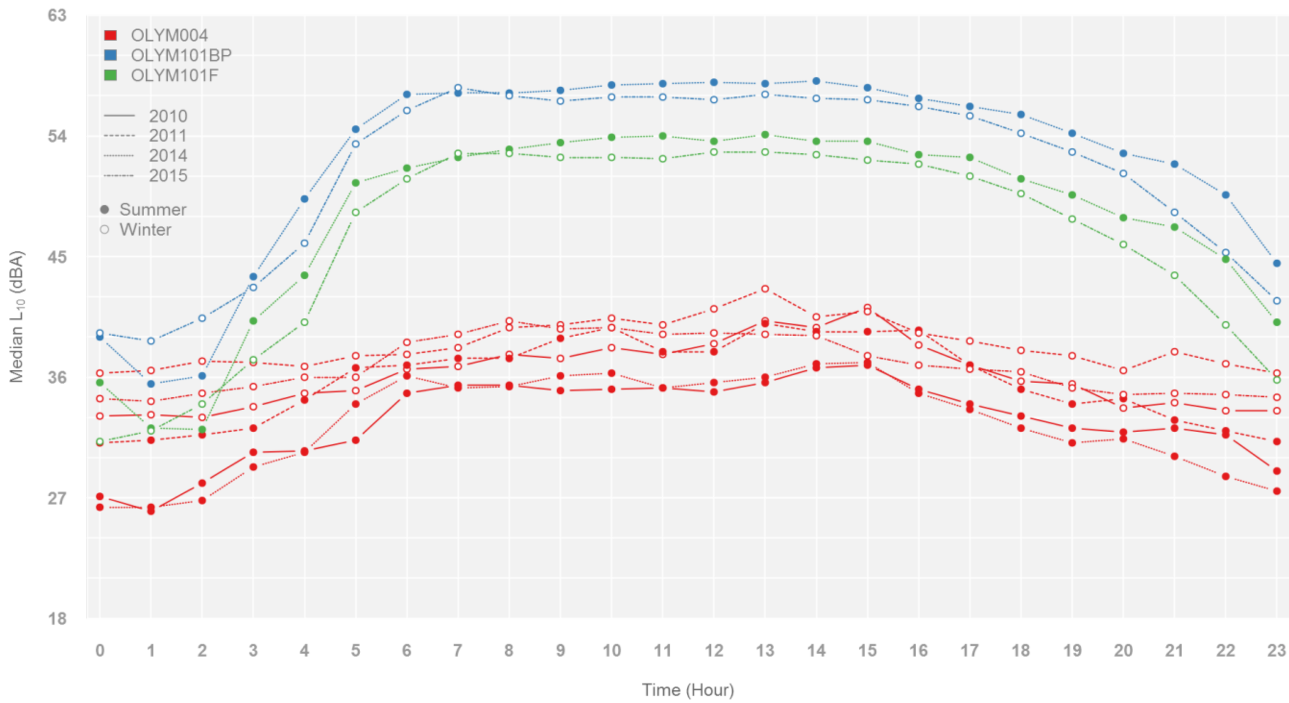
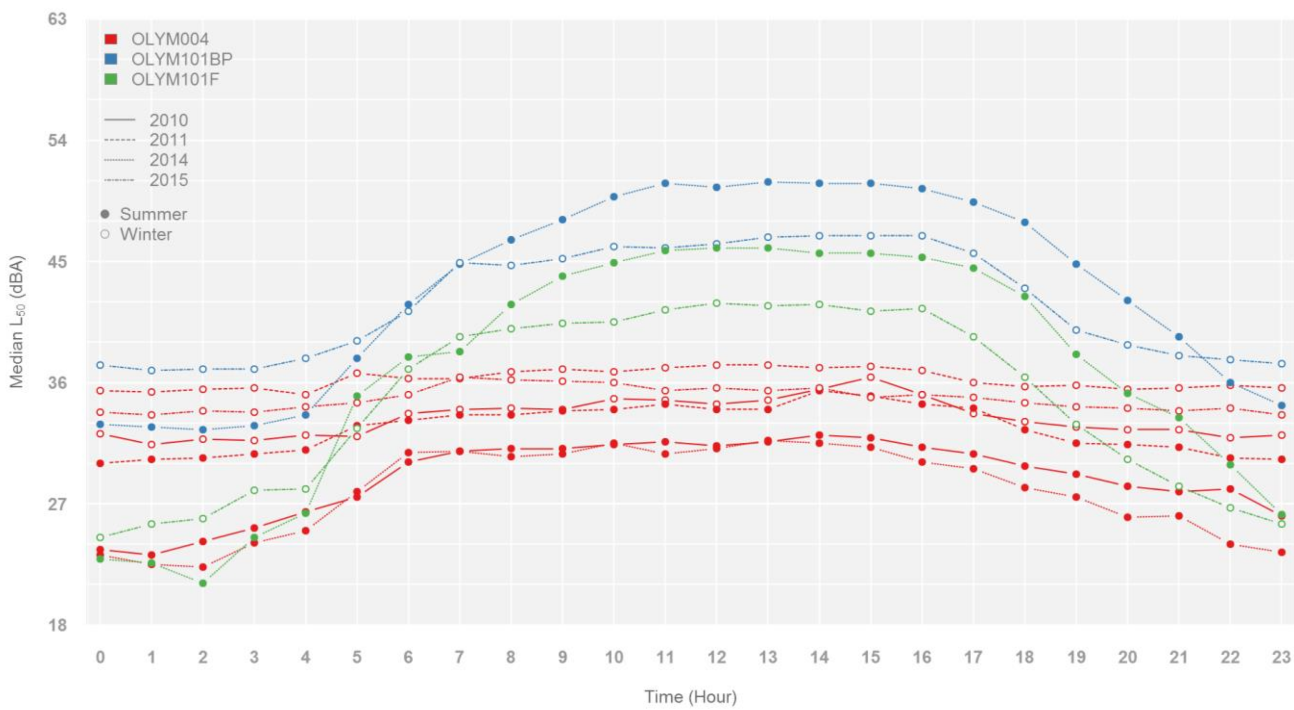
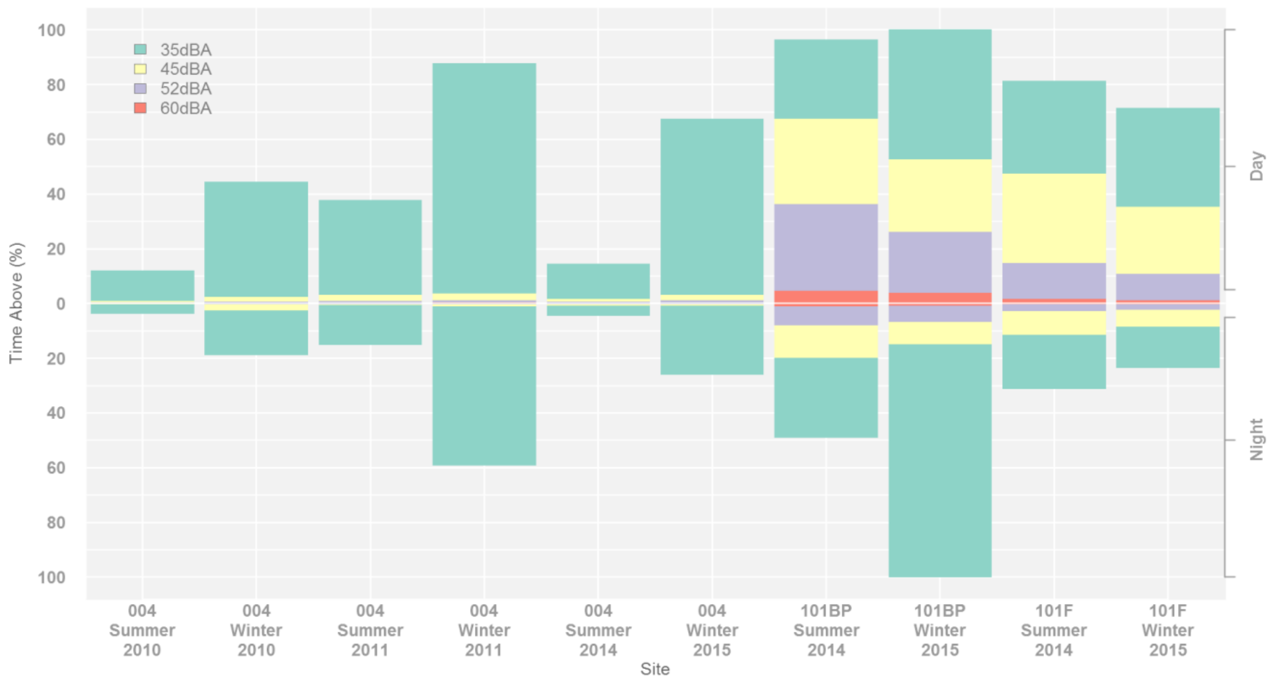


Figure 17: The average sound pressure levels over the course of a typical day at all three sites, during each monitoring season. This can be considered the hourly ambient for each of the sites.



In addition to seasonal variation we also see daily variations in SPL (Figures 16-17). In all cases, sound levels were higher during the daytime than they were at night. This difference was more pronounced during the summer, and is likely a result of increased daytime traffic. The loudest 10 percent of noises at the highest daily peak of traffic are above 50dBA at OLYM101F and 57 dBA at OLYM101BP. At the OLYM004 site this daily peak in traffic is much less noticeable in the winter than the summer. This noise levels during certain times of day will be important to consider when monitoring the effects of noise on a crepuscular species like the Marbled Murrelett. In Figure 18 we see that the data from the OLYM101BP Winter 2015, the loudest site, exceeds 35 dBA 100% of the time but the loudest sounds that are higher than 45, 53 and 60 dBA are most common during the day. Exceedance levels where higher in the summer sites than the winter sites at OLYM101BP and OLYM101F (figure 18), this suggests higher traffic noises during the summer days than the winter days. This difference between daytime and nighttime SPL at all the sites is best visualized in figures 6-14.

Figure 18: The day and night percent time above critical thresholds at each site.



While on-site listening session measurements do provide some information on sound sources, these sessions aren't done frequently enough to give us the full acoustic picture. The Pyramid Peak site had three seasons (9 hours) of data collected, two from winter (2010, 2015) and one from summer (2014). The OLYM101BP and OLYM101F site each had two seasons (8 hours) of data collected in the summer of 2014 and winter of 2015. The OLYM101BP and OLYM101F sites had a higher percent time audible from traffic related noise sources in the summer than in the winter. The only time "flowing water" and "rain/fog drip" were recorded in these sessions was in the winter season at all three sites. Non-natural sound-sources dominated the soundscape at OLYM101BP and OLYM101F more noticeably than at OLYM004 according to the attended listening sessions.

Literature Cited

American National Standards Institute. 2002. Standard S12.60-2002, American national standard acoustical performance criteria, design requirements, and guidelines for schools.

Barber, J.R. and Others (2009-2010). Conserving the wild life therin: Protecting park fauna form anthropogenic noise. Park Science: State of Science. Vol 29. **3**. 26-31.

Berglund, B., Lindvall, T., & Schwela, D.H. (Eds.). 1999. Guidelines for community noise. World Health Organization, Geneva.

Dooling, R., & Popper, A. (2007). *The effects of highway noise on birds*. Rockville, MD: Environmental BioAcoustics LLC.

Haralabidis, A, Dimakopoulou, K., Vigna-Taglianti, F., Giampaolo, M., Borgini, A., Dudley, M., Pershagen, G., Bluhm, G., Houthuis, D., Babisch, & others. 2008. Acute effects of night-time noise exposure on blood pressure in populations living near airports. European Heart Journal **29**:658-664.

Harris, C. M. (1998). *Handbook of Acoustical Measurements and Noise Control,* 3rd ed. McGraw-Hill, New York.

Holmgren AL and Others. 2014. North Coast and Cascades Network landbird monitoring: Report for the 2013 field season. Natural Resource Data Series. NPS/NCCN/NRDS—2014/691. National Park Service. Fort Collins, Colorado. Published Report-2215242.

U.S. Environmental Protection Agency (EPA). 1974. Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety. EPA, Washington, D.C.

U.S. Fish and Wildlife Service (USFWS). 2006. Estimating the Effects of Auditory and Visual Disturbance to Northern Spotted Owls and Marbled Murrelets in Northwestern California. Arcata Fish and Wildlife Office.

U.S. Fish and Wildlife Service (USFWS). 2008. Biological Opinion for the Olympic National Park General Management Plan and ongoing Programmatic Park Management Activities 2008-2012. U.S. Fish and Wildlife Service Reference: 13410-2007-F-0644. Lacey, Washington.

U.S. National Climatic Data Center (NCDC). College of the Environment University of Washington. 2011. Web. <http://www.atmos.washington.edu/marka/normals/>.

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